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THE STUDY OF THE PHYSICO-MECHANICAL PROPERTIES OF FASHION TIGHTS COMPARED TO MEDICINAL TIGHTS

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Abstract: The aim's paper was to study some physico-mechanical properties for fashion tights and medicinal tights with compression degree 1 (ie 10-15 mm Hg), class 1, for the prevention of venous diseases of the legs. Tights made of PA (polyamide) and two-component yarns, polyamide, and elastane, with a fineness of 70 Den, were chosen for the study. For fashion tights, the yarn composition was 88% polyamide and 12% elastane, and for medicinal tights 85% polyamide and 15% elastane. The tights were made on circular knitting machines with small diameter, Merz, model CC4 II with a diameter of 4 ¾ inches, pitch 24 E, number of needles 360, for the average size, M (II) of the tights. Both types of women's tights were made in a jersey structure with weft yarns. The background yarns were 100% polyamide, and the weft yarns were elastomer yarns coated in two polyamide yarns to obtain a balanced yarn. Fashion tights are the common ones, and compressive tights are used to prevent incipient venous disorders of the legs, calming the sensation of pain or heavy legs. The experimental program included the study of hygroscopicity, the tensile strength in the direction of the wales, and the degree of compression at the ankle. The obtained data were analysed and presented comparatively.
Key words: fashion tights, medicinal tights, wearing comfort, degree of compression, hygroscopicity, tensile strength.

1. INTRODUCTION

Tights, fashion or compressive, are items that enhance an outfit. For fashion tights, colour matching seems to be enough, but the problem is more complex because the aspects related to the wearing comfort and the deformations on the direction of the courses and wales during wearing are decisive elements for choosing a certain type of tight. The choice of fashion tights considering the dimensional stability must be made so that they do not form creases on the foot during wearing, do not slip from the waist, or do not produce too much compression in the abdominal area and when fixing on the waist [1].

Compressive tights are therapeutic and can be worn with caution to replace fashion ones. They must be properly sized; otherwise, their effects may be severe, so usually, the tights are purchased with a medical prescription. Too much compression of the tights in the legs creates a discomfort that leads to giving up wearing them. A lower compression is not recommended because then these tights no longer fulfill their role. There are two types of compressive tights: with uniform compression for the entire length and with higher compression in the ankle area which compression decreases towards the top of the tight. A higher compression of the tights in the abdominal area creates pressure on the intra-abdominal organs and they will exert pressure on the diaphragm, the diaphragm on the heart, and thus, in extreme situations, even heart failure can occur. Another indication for wearing compressive tights is to wear them only during the day when the body is for a long time in an upright position. It is not recommended to wear therapeutic tights during the night because they do not fulfill their role, that of helping to improve the venous return of the blood, and when changing the position of the body from horizontal to vertical, rapid increases in blood pressure can occur with unpredictable effects [2-6].

Knitwear, by definition, is elastic structures made of stitches. In the case of jersey knits, the tensile deformation in the course's direction is much higher than in the wales direction and can reach up to 30%. The degree of deformation depends on the type of yarn from which the knitting is made and the vertical density imposed by the design. The elongation at break in the direction of the courses is explained by the migration of some quantities of yarns from the sides of the stitches to the needle and platinum loops. As a result, the needle and platinum loops become straight segments, and the sides of the stitches will turn from straight segments into semi-circular curves. By

inserting weft yarns into the structure, the elongation in the direction of the courses of stitches is greatly diminished and will become dependent on the elongation of the weft yarn [7-9].
To perform the comparative study between the two types of tights, the fashion and the compressive ones, we analyzed knitted tights on the same type of machine, with identical technical characteristics, made of yarn of the same fineness and in the same structure, the tights being of the same size, the medium one. The composition of the yarns was different but in accordance with the destination of the products.

2. MATERIALS AND METHODS

Tights made of two-component yarns, polyamide, and elastane with a fineness of 70 Den were chosen for the study. For fashion tights, the yarn composition was 88% PA and 12% elastane, and for medicinal tights 85% PA and 15% elastane. The tights were made on circular knitting machines with small diameter, Merz, model CC4 II with a diameter of 4 ¾ inches.
The technical characteristics of the Merz knitting machine, model CC4 II on which the samples were knitted are presented in Table 1.

Table 1. The technical specifications of the Merz CC4 II knitting machine

Technical specifications							
Needle dial diameter [inch]	Pitch [E]	Number of needles	Number of cam systems	Number of yarns guides	Needle bad rotation speed [rpm]	Engine power [Watt]	Power frequency [Hz]
4 ¾	E 24	360	4	34	280	400	50-60

The tights were knitted in the same structure, jersey with weft yarns. Weft yarns were filed in front and behind the stitches of the jersey structure, and their role was to shape the tights and exert a predetermined compression, in the case of compressive tights. Due to the way the weft yarn was laid, it can be removed from the structure, intentionally or accidentally, the resulted appearance being a defect in the direction of the rows.
The jersey structure with weft yarns of the analysed tights is presented in Figure 1, according to ISO 23606:2009 – Textiles – Knitted fabrics – Representations and pattern design.
The fashion and medicinal tights with compression degree 1 (ie 10-15 mm Hg) were evaluated for hygroscopicity, degree of compression, and tensile deformations in the wales direction. The studied compressive tights exert a uniform compression on the ankle, knee, and thigh.

2.1 Hygroscopicity

For hygroscopicity determination, the SARTORIUS MA 100 balance was used, at a temperature of 105℃.

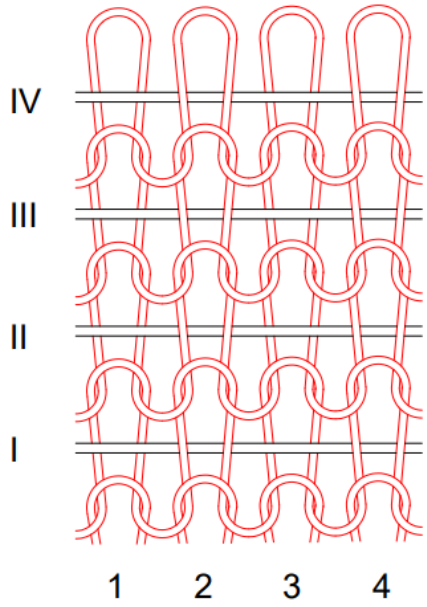

Fig. 1. The jersey structure with weft yarns (rear appearance)

2.2 Tensile strength in the wales direction

The standards EN ISO 14704-3 / 2007 for the determination of fabric elasticity - Tests on the fabric (classification index: G07-200-1) - 2005, NF EN ISO 14704- 2 Determination of fabric elasticity - Multiaxial tests (classification index: G07-200-2) - 2007, NF EN ISO 14704-3 Determination of fabric elasticity - narrow fabrics (classification index: G07-200-3) – 2007 were used to analyse the tensile strength of the tights. The determinations were made at the ankle level of the tights.
Samples were conditioned 12 hours in air-conditioned rooms with the parameters of the standard atmosphere T = 20 ± 20C, p = 760 mm colHg = 1 atm, φ 65 ± 5%.%. Three specimens with the size of 50 mm x 150 mm from each type of tights were taken from the wales direction and analysed with an EMI dynamometer. The distance between the clamps was set to 150 mm ± 1 mm, the sample was attached to the fixed upper clamp and by using the lower movable clamp was subjected to tensile strength evaluation at an elongation of 30% and 60%, with a speed of 200 mm/min.

2.3 The degree of compression

The degree of compression was determined in the ankle area for both types of tights using the standard NFG 30 102 - Textiles - Knitted goods - Determination of restraining force.
The analysed samples were washed, dried, and conditioned for 24 hours in a standard atmosphere. The specimens were placed on the measuring mannequin and lightly massaged to obtain the maximum density in the ankle area.
The degree of compression was determined with an

EMI dynamometer. It was determined in 3 areas at the ankle: minimum, medium, and maximum, respectively on the lines described by points A, B, and C (see Figure 2). The speed of the mobile clamp was set to 100 mm/min. Each sample was subjected to 6 elongations and the pressure was calculated with the force recorded during the sixth cycle.

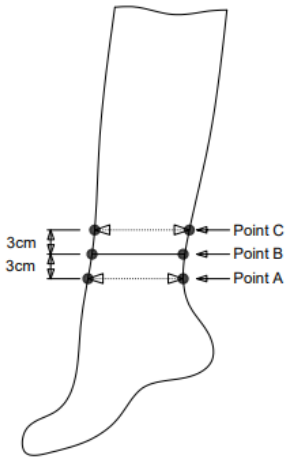

Fig. 2. The compression lines

3. RESULTS AND DISCUSSION

3.1 Hygroscopicity

The The hygroscopicity of the tights is an important parameter for wearing comfort and the sanogenetic capacity of the products. The water content of the yarns influences the mechanical, thermal properties, and dimensional stability. The absorption capacity of the vapours must be around 4% in conditions of relative humidity of 65% to ensure a proper release to the outside environment.

The results of hygroscopicity for compressive and fashion tights are presented in Table 2.

Table 2. The hygroscopicity values for compressive and fashion tights

Sample	Weight/piece [g]	Hygroscopicity [%]
Compressive tights - 70 Den 85% PA and 15% elastane	47.027	4.1
Fashion tights - 70 Den 88% PA and 12% elastane	75.970	3.9

Compressive tights have higher hygroscopicity compared to fashion ones due to the higher compactness of the knit and the specific finishing operations for medical articles. Higher hygroscopicity provides superior wearing comfort, making it possible to use therapeutic tights daily with all the benefits of preventing venous disease of the lower limbs.

3.2 Tensile strength in the wales direction

The tensile strength of the analysed tights was calculated according to the equation (1):

$$F[cN/cm] = \frac{F_{determined}[cN] \cdot 100}{l\,[cm]} \quad (1)$$

where: F - the resulting force per cm [cN/cm]; $F_{determined}$ - the force indicated by the dynamometer [cN]; l– specimen's width (50 mm).

In Table 3 and Table 4 are centralized the data for the tensile strength analysis of the compressive and fashion tights. Figures 3 and 4 present the tensile strength behaviour in the wales direction for class 1 compressive tights and for fashion ones.

Table 3. Data for the tensile strength evaluation of the compressive tights

Upper limit 200 Lower limit 0	Specimen width [mm]	Deformation position 1 [mm]	Deformation position 2 [mm]	Deformation force 1 [N]	Deformation force 2 [N]	Deformation force 1 average [cN/cm]	Deformation force 2 average [cN/cm]
Average	50	30	60	0.6695	1.153	13.39	23.07

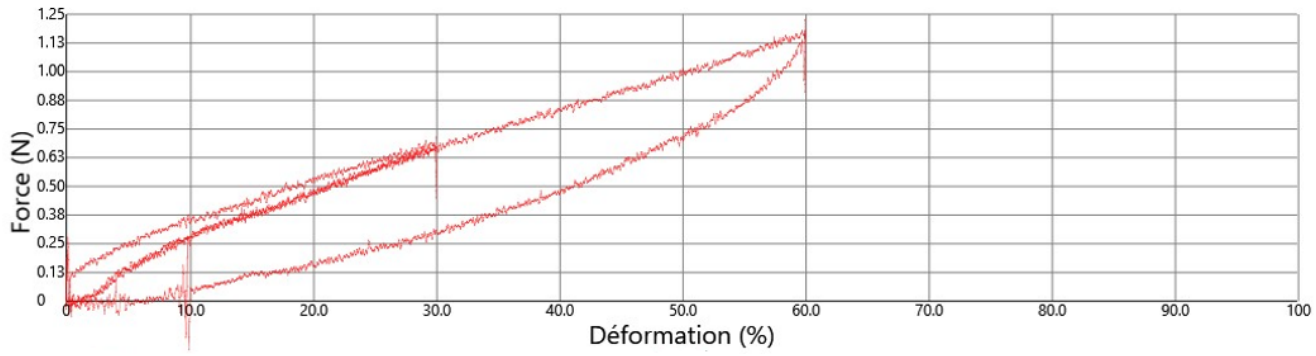

Fig. 3. Tensile strength behaviour in the wales direction for class 1 compressive tights

Table 4. Data for the tensile strength evaluation of the fashion tights

Upper limit 200 Lower limit 0	Specimen width [mm]	Deformation position 1 [mm]	Deformation position 2 [mm]	Deformation force 1 [N]	Deformation force 2 [N]	Deformation force 1 average [cN/cm]	Deformation force 2 average [cN/cm]
Average	50	30	60	0.473	0.9333	9.525	18.67

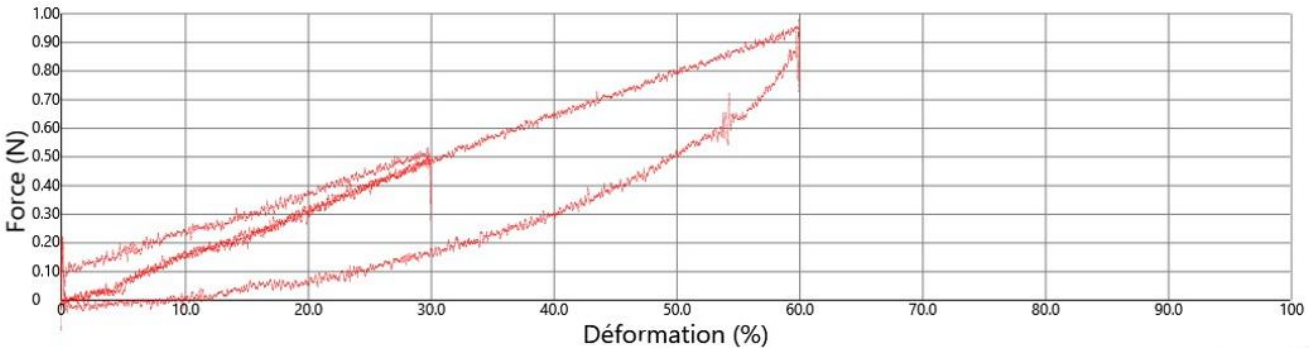

Fig. 4. Tensile strength behaviour in the wales direction for fashion tights

The results of the determinations are centralized in Table 5.

Table 5. Data for the tensile strength evaluation of the compressive and fashion tights

Product	Direction	Size	Resulting force (cN/cm) at an elongation of 30%	Resulting force (cN/cm) at an elongation of 60%	Limits
Compressive tights	Wales	M	13.39	23.07	0-150
Fashion tights	Wales	M	9.52	18.67	0-150

The analysis of Figure 3 and Figure 4 shows that for deformations of 30% and 60% in the vertical direction of the wales of stitches, higher tensile forces are required for class 1compressive tights than for fashion ones. The explanation is that for the compressive tights, the elastomer yarn was filed with higher tension and thus the wales of stitches tend to get closer conducting to a larger number of wales per 50 mm wide of the specimen.

3.3 The degree of compression

The compression force was calculated based on the ankle circumference and the measuring width imposed by the NFG 30 102 Textiles - Knitted goods - Determination of restraining force standard, which in this case was 30 mm.

Table 6 summarized the data for the degree of compression testing of the compressive and fashion tights.

The following equations were used to calculate the degree of compression:

$$P = \frac{2 \cdot \pi \cdot F}{C_m \cdot l} \ [hPa] \qquad (2)$$

$$C_m = \frac{C_{min} + C_{max}}{2} \ [mm] \qquad (3)$$

where: C_{min} - the minimum circumference in the stretched state on the ankle line;

C_{max} - the maximum circumference corresponding to the size, on the ankle line;

C_m - the average circumference on the ankle line.

Table 6. Data for the degree of compression testing of the compressive and fashion tights

Measured ankle size in a relaxed state [mm]	Minimum circumference in the extended state (C_{min}) [mm]	The maximum circumference corresponding to the product's size (C_{max}) [mm]	Drawing speed [m/min]	Measuring width [mm]
202	240	260	100	30

The compression classes for tights are presented in Table 7. In Table 8 the values of the compressive forces determined at the level of the ankle and the classification in the compression class for the analysed tights are centralized.

Table 7. The compression classes for tights

Class 0	Class 1		Class 2		Class 3		Class 4
[hPa]	min. [hPa]	max. [hPa]	min. [hPa]	max. [hPa]	min. [hPa]	max. [hPa]	[hPa]
less than 13	13	20	20.1	27	27.1	48	over 48
[mmHg]	min. [mmHg]	max. [mmHg]	min. [mmHg]	max. [mmHg]	min. [mmHg]	max. [mmHg]	[mmHg]
less than 10	10.0	15.0	15.1	20.0	20.1	36	over 36

Table 8. The compressive forces determined at the level of the ankle and the classification of compressive and fashion tights in the compression class

Sample	First cycle force [N]	Last cycle force [N]	Pressure / cycle [hPa]	Pressure for the last cycle [hPa]		Final pressure [hPa]	Degree of compression
Compressive tights	3.847	3.838	16.11	Upper limit	20.00	16.07	Degree of compression 1
				Lower limit	13.00		
Fashion tights	1.637	1.600	6.854	Upper limit	13.00	6.701	Degree of compression 0
				Lower limit	1.00		

Figure 5 and Figure 6 show the behaviour of compressive and fashion tights at the ankle compression test.

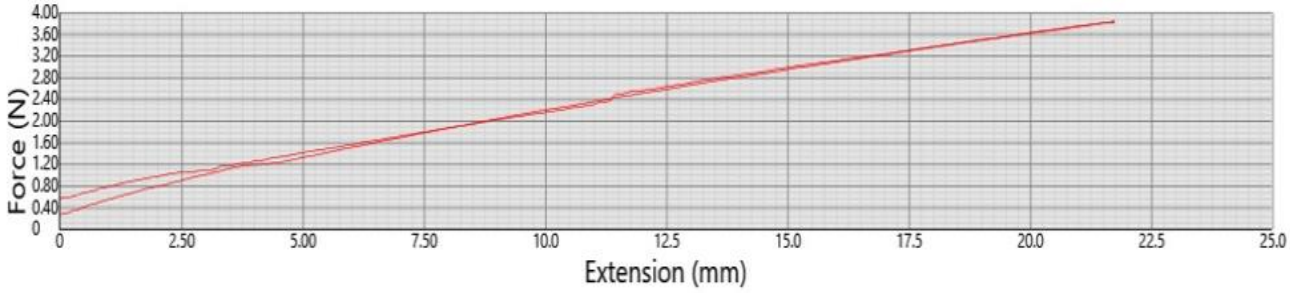

Fig. 5. Behaviour of compressive tights at the ankle compression test

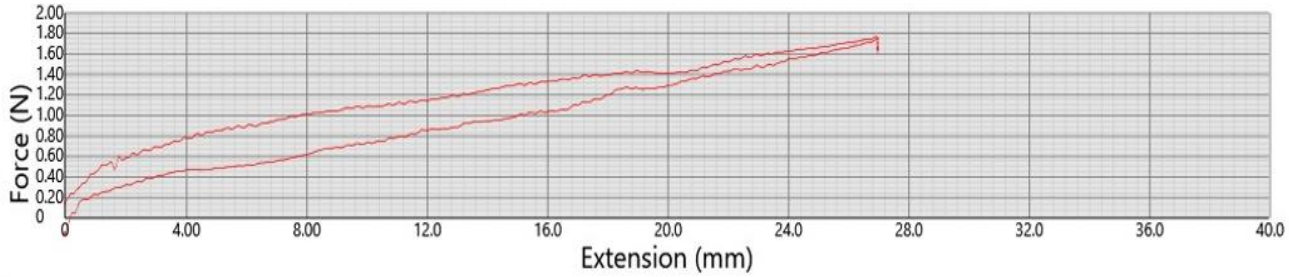

Fig. 6. Behaviour of fashion tights at the ankle compression test

The analysis of the two figures shows an ankle pressure of 16.07 hPa for compressive tights compared to 6.701 for fashion tights. The value of 16.07 hPa leads to the classification of the compressive tights in compression class 1. Fashion tights have zero degrees of compression.

4. CONCLUSIONS

Women's tights are an item that can only have an aesthetic role, being an integral part of an outfit, or can have an aesthetic and therapeutic role simultaneously. The analyzed tights comply with one of the essential parameters regarding the wearing comfort appreciated in this case by hygroscopicity, which is in the limit of 4% specific to PA and elastomer knitwear.

The tensile strength in the direction of the wales of stitches is higher for the compressive tights, both for the 30% and for the 60% solicitation, and is explained by the higher number of elements, rows of stitches, and weft yarns on the width of 50 cm of the test specimen subjected to analysis.

Because they are included in compression class 1, medicinal tights exert a pressure of 16.07 hPa on the ankle and may be recommended for daily wear to people who are doing long-standing activities. Class 1 compression tights can prevent minor circulatory problems in the legs.

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